Experimental Study on Infiltration Pattern and Assessing Spatial Variability of Engineering Properties of Soil in Junagadh Taluka (Gujarat-India)

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By

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DECEMBER - 2025

CERTIFICATE

This is to certify that the thesis entitled **"Experimental Study on Infiltration Pattern and Assessing Spatial Variability of Engineering Properties of Soil in Junagadh Taluka (Gujarat-India)"** is a bonafide record of research work carried out by **Kalola Amit Chunilal** (Enrol. No. **220810340006**), Research Scholar, Department of Civil Engineering, School of Engineering and Technology, Dr. Subhash University - Junagadh, under our supervision/guidance during the period *August 2022 – December 2025*. To the best of our knowledge: (I) the candidate has not submitted the same research work to any other University or Institute for any Degree, Diploma, Associateship, Fellowship or other similar titles (II) the thesis submitted is a record of original research work done by the Research scholar during the period of study under our supervision, and (III) the thesis represents independent research work on the part of the Research scholar.

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DECLARATION

I, **Kalola Amit Chunilal**, Research scholar in the Department of Civil Engineering, declare that the work embodied in the Ph.D. thesis entitled, **"Experimental Study on Infiltration Pattern and Assessing Spatial Variability of Engineering Properties of Soil in Junagadh Taluka (Gujarat-India)"** is my original and bonafide work carried out by me under the supervision of **Prof. (Dr.) Arpit A. Parikh**, Professor, Dr. Subhash University and the Co-supervision of **Prof. (Dr.) Manoj J. Gundalia**, Professor, Uka Trasaida University for a period from *August 2022* to *December 2025* at Dr. Subhash University.

I further declare that the contents embodied in this thesis have not been submitted for the award of any degree, diploma, associateship, fellowship or other similar title to any other University or Institute.

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Abstract

Infiltration is a key hydrological process that significantly affects ground water recharge, soil moisture availability and overall agricultural productivity especially in semi-arid and rain fed areas. Accurate estimation of infiltration is essential for effective water resource management, land use planning, and the implementation of sustainable agricultural practices. However, traditional methods often fail to account for spatial, temporal, and environmental variations, limiting their applicability in heterogeneous landscapes. To address this gap, the present study investigates the spatial and temporal variability of infiltration rates across 24 villages of Junagadh Taluka, Gujarat, India. Field measurements were carried out using a Double Ring Infiltrometer (DRI) across diverse land use patterns and soil textures. The Horton's and Philip's Infiltration Models were applied to the observed data to simulate infiltration behavior and derive decay constants and equilibrium infiltration capacities. The Horton's model demonstrated an excellent fit between observed and predicted infiltration rates, confirming its suitability infiltration Pattern for the study area.

Results revealed substantial variability, with higher infiltration rates in forested areas (4.82 cm/h) and lower rates in compacted urban zones (1.2 cm/h). Initial infiltration rates were high but declined exponentially over time, consistent with Horton's decay pattern, indicating soil saturation and structural variability. Temporal analysis between 2023 and 2024 showed improvements in villages such as Khadiya (3.64 cm/h) and Toraniya (3.62 cm/h) due to better soil and water management, while Padariya (2.41 cm/h) and Makhiyala (1.21 cm/h) experienced declines resulting from compaction and land degradation. Statistical evaluation of bulk density, dry density, water content, and infiltration variability supported these findings and highlighted localized influences on infiltration behavior. The integration of field measurements, Horton's modeling approach, and geospatial analysis provided a comprehensive understanding of infiltration dynamics and performance of Horton model 62.5% in 2023 year to 95.8% in 2024 year compare with Philip's model. The study emphasizes that combining empirical models with environmental parameters enhances the precision and applicability of infiltration studies. These insights contribute to data-driven decision-making for climate-resilient water management. As climate variability increasingly impacts soil water interactions, the ability to model and monitor

infiltration accurately becomes vital for sustaining agricultural productivity and long term environmental health.

Chapter 1
Introduction

The soil water infiltration process is a key hydrological process with significant ramifications across diverse fields including soil science, physical geography, hydrology, drainage, hydrogeology, and irrigation engineering. Infiltration is the ability of water to move through the soil layers, and it is critical in governing the spatial distribution of water within the soil profile which impacts groundwater recharge, surface runoff and water availability for agriculture [1]. Primary metrics of this process are cumulative infiltration, the total volume of water taken up by soil at a period of time; immediate Infiltration Rate (IR) which is the rate of water entering the soil at a specific point in time; and general IR which soil's capacity to receive water from rainfall or irrigation over a period [2]. IR is affected by many factors such as the initial moisture content of the soil, rainfall intensity and duration, temperature of soil and water, biological activity, soil texture, porosity, compaction and surface cover [3]. Field measurement of IR is usually performed using a single or Double Ring Infiltrometer (DRI) with double ring being preferred since it can minimize errors associate with lateral water flow [4]. As long as the same depth between the inner and outer ring is maintained while measuring the vertical flow into the inner ring, accurate measurements of IR can be established.

The Junagadh Taluka, located in the western part of Gujarat, India offers a unique background for infiltration measurements based on the various soil properties, landform and climate characteristics [5]. The soil is predominantly loams, and there is a calcareous upper horizon and a deeper stony layer, referred to as karalpan [6]. Water drains quickly in this region, which represents the immediacy of sustainable water management and groundwater recharge need [7]. To effectively manage water resources, we need detailed knowledge of infiltration patterns, which can help to identify suitable recharge areas, avoid waterlogging and maintain agricultural productivity [8]. Soil physical properties of structure, texture, porosity, bulk density and moisture content directly impact infiltration and thus, available water and soil health [9]. Properties such as bulk density, gravity water content and permeability are particularly important since they dictate soil compaction, water holding capacity, aeration and root development [10]. It is necessary to understand the properties and characteristics for sustainable land management,

optimizing irrigation applications, minimizing erosion and conserving limited water resources. More reliable and precise methods to measure infiltration, such as DRI will offer reliable information on the spatial variability of IRs to derive reliable information for a specific groundwater recharge case, and water resources case in places like Junagadh taluka.

Chapter 2
Literature Review

The various aspects of the literature review are provided based on soil infiltration patterns and spatial variability of engineering properties. Some are given as follows;

In 2024, SBM Hassan et al. [11] recommended soil Hydraulic Properties (HP) and Vegetation Parameters (VP) spatial variation as important for modeling agro hydrological processes and for irrigation volume optimization on a large scale. Results showed that ignoring VP (RVS-VP) variation made a relative minor difference in either the optimal irrigation volume or the deep percolation fluxes. However, neglecting HP variation (RVS-HP) made considerable changes to irrigation and deep percolation volumes compared to the DVS setting.

In 2024, J Wang et al. [12] conducted a study to investigate the responses of emitter flow rate and soil back pressure in silty loam soil. The infiltration cavity was evaluated and the estimated infiltration cavity radius was based on the observed emitter flow rate and soil back pressure through HYDRUS-2D simulations. The results indicate that infiltration cavity development occurred rapidly during irrigation and had an irregular shape.

In 2024, J Liu et al. [13] investigated the changes in resistance to soil erosion over time and the factors involved in the development of PSC through the effects of natural weather conditions on the soil plots for 524 days on the Loess Plateau which included two wet seasons and a winter between them. The findings indicate that the development of PSC improves soil erosion resistance during the soil detachment process in the loess region under natural environments. It has indicated the significant role and complexity of PSC in the soil erosion process and provided theoretical and data support for a better understanding and prediction of soil erosion.

In 2025, G Verma et al. [14] investigated spatial variation in potential methane oxidation and residual CO_2 sequestration within a Biogeochemical Cover (BGCC) system designed to remove CH_4, CO_2, and Hydrogen Sulfide (H_2S) from Land Fill Gas (LFG) emissions. The objective of

the study was to assess the effectiveness of BGCC in reducing LFG. However, research mainly focuses on the study of spatial variations in physicochemical properties, methane oxidation in the BAS layer and residual carbonation in the BOF slag layer.

In 2023, W Cao et al. [15] introduced a combined approach for assessing the stratigraphic uncertainty and rotated anisotropy of soil characteristics while examining the stability of unsaturated soil slopes in light of these two uncertainties. The findings indicate that the suggested approach effectively captures both uncertainties simultaneously. The angles of rotation corresponding to the highest and lowest reliability indices of the slope were influenced by the uncertainty factors considered in the assessment of slope stability.

In 2023, JB Gonzalez et al. [16] studied the spatial distribution of eight top soil types in a small grazed catchment. Using four different machine learning methods, Random Forest (RF), Support Vector Machines (SVM), Cubist and K Nearest Neighbors (KNN), they found important information regarding how well the models were performing and providing a reference for future research on predicting soil properties. Ultimately, they point to a need for more research in small watersheds on improving soil and land management.

In 2023, BN Shashikumar et al. [17] utilized spatial variability in soil nutrients as a technique to define Management Zones (MZs) in a watershed located in the mid Himalayas. They prepared and analyzed samples for soil pH, Electrical Conductivity (EC), Aggregate Stability (AS), Clay Content (CL), Total Carbon (TC), Total Nitrogen (TN), Available Phosphorous (AP) and Available Potassium (AK). Analysis of variance indicated significant differences in soil and terrain properties across the MZs. The analysis of the MZs using cluster analysis also demonstrated differences useful for farmers for executing soil management strategies at a site-specific level.

In 2025, J Gao et al [18] presented a new approach that combines fuzzy logic with Geographically Weighted Regression (GWR) to improve groundwater potential mapping. Important findings reveal considerable spatial variation in groundwater potential, particularly in the southern regions which exhibit superior potential for recharge due to advantageous geological factors. These findings provide important information for those in the hydrology field to aid in the development of sustainable groundwater management strategies and focused interventions for water resources in different environmental contexts.

In 2024, Y. Jiang et al. [19] used the MIKE flood model to investigate how flooding evolves spatially and temporally in a densely populated urban area, examining how different locations of rainfall extremes and infiltration rate conditions influence urban waterlogging characteristics. The findings indicate that for a specific return period, a higher rainfall peak coefficient corresponds to a larger peak flood volume and flood area.

In 2025, Z. Fu et al. [20] investigated the potential of Subsurface Flow (SSF) at the interface between soil and bedrock as a valuable water resource that can improve the effectiveness of conventional Surface Flow (SF) based Rainwater Harvesting (RWH) systems. The results show that SSF outperforms SF especially during periods of heavy rainfall. These findings have important implications for the management of water resources in comparable geological contexts.

2.1 Definition of the Problem

The infiltration, the process through which the water enters the soil surface and moves downward, is severely affected by the physical properties of the soil such as the texture, structure, holes and condensation. However, significant spatial variability in infiltration rates in various fields creates a major challenge for accurate hydrological modeling, permanent land use scheme and efficient water resources management. The issue has been pronounced especially in areas such as Junagadh Taluka in Gujarat, where field studies have detected considerable asymmetry in infiltration behavior due to soil texture, slope, moisture content and variation in land management practice. Traditional infiltration models often fail to catch this local variability, leading to ineffective water conservation strategies and poor irrigation scheme. Furthermore, field based infiltration studies in the region have shown that existing functioning lacks spatial resolution and adaptability required to reflect dynamic environmental conditions. The boundaries in measurement techniques and an absence of integrated analysis devices make it difficult to establish an accurate relationship among infiltration rates and affecting soil parameters. To overcome these challenges, needs to develop specific and data powered approach that combines better field measurement techniques with detailed spatial analysis of soil properties. It includes high resolution sampling in various scenarios, using enhanced intruders capable of capturing variations and adopting analytical model calibrated especially for local conditions. Integrating such approaches will help identify infiltration hotspots and low performing areas which can lead to targeted soil and water conservation practices. Moreover, understanding the dynamics of

infiltration in relation to specific land uses and soil management history will support the more effective agricultural plan and decrease the risks of runoff and erosion. Finally, localized, empirical research, while addressing the spatial variability of infiltration, can improve the forecast accuracy of hydrological assessment to suit the unique conditions of areas such as Junagadh and support permanent land and water resources management.

2.2 Objectives

The objectives of the research are given below;

- To analyze the process of infiltration in various soil types in Junagadh region.
- To assess the spatial variability of infiltration within the arid and semi-arid regions of Junagadh taluka.
- To identify the appropriate model for infiltration in Junagadh taluka.

2.3 Contribution of the Thesis

The key contributions of the research are:

- A comprehensive evaluation of spatial variability across black cotton soil type in Junagadh Taluka using a DRI method offering detailed, location-specific infiltration data for the regional water scheme.
- The facility of evidence based approach for permanent land management and agricultural development in dry regions, assessment of land use pattern and their impact on soil infiltration capacity.
- ASTM D3385 standard is followed for scientific accuracy and stability with national soil testing standards for infiltration measurement
- The provision of practical data to support water resources decision making, especially about efficient water use for irrigation planning and water conservation in water door areas like Junagadh.
- Identifying soil areas with low or high infiltration capacity, improvement intervention in targeted soil and prioritizing conservation efforts where they require the most.
- Helping the contribution of infiltration with soil suitability for crop cultivation, helping farmers and planners to select proper land use strategies.

- ❖ Promotion of localized research methods by displaying how field-specific soil testing can generate valuable data to support ecological stability and water safety initiatives.
- ❖ Support for integrated water and soil conservation schemes especially in region ecosystems where infiltration controls the balance between surface runoff, groundwater recharge and erosion control.
- ❖ The generation of a scientific base for future research on sustainable agriculture in the infiltration modeling, soil water relations and uniform agricultural class areas enhances the widespread prevention of conclusions.

Chapter 3

Research Methodology

In this section, the proposed methodology is discussed. The study follows a comprehensive and systematic method to evaluate soil infiltration characteristics in many villages using both the standard field practices and infiltration models. This study starts with the selection of the field and identification of sample villages. Subsequently, terrain and satellite data are collected to understand the area, land use pattern and initial site conditions. Figure 1 shows the flowchart for proposed methodology.

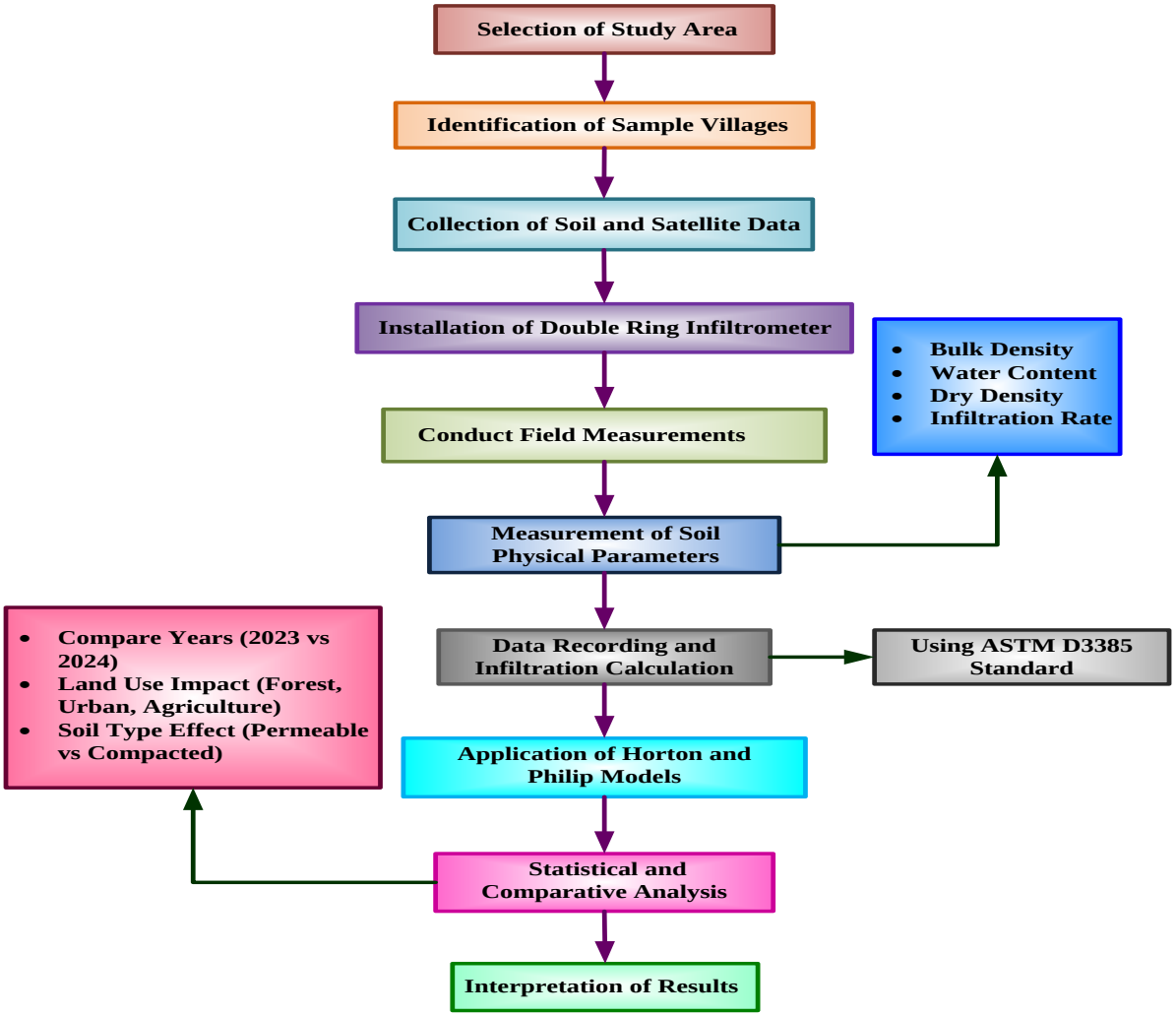
Selection of Study Area
Identification of Sample Villages
Collection of Soil and Satellite Data
Installation of Double Ring Infiltrometer
Conduct Field Measurements
Measurement of Soil Physical Parameters
Bulk Density
Water Content
Dry Density
Infiltration Rate
Data Recording and Infiltration Calculation
Using ASTM D3385 Standard
Application of Horton and Philip Models
Statistical and Comparative Analysis
Compare Years (2023 vs 2024)
Land Use Impact (Forest, Urban, Agriculture)
Soil Type Effect (Permeable vs Compacted)
Interpretation of Results

Figure 1: Proposed Methodology

Field work involves the installation of a DRI which is necessary to accurately measure infiltration rates in standardized conditions. It is supported by the measurement of physical parameters of the major soil such as bulk density, dry density and moisture content as per guidelines I.S. 2720 (29) 1966 and I.S. 2720 (Part II) – 1973, which affect all infiltration behavior. The data collected from these measurements is processed to calculate the infiltration rates which are to ensure stability and reliability after the standards of ASTM D3385. To enhance analytical structure, the study includes Horton and Philips two widely accepted infiltration models that help simulate and interpret infiltration processes under various soil and moisture conditions. The application of these models allows understanding the major parameters and understanding of the dynamics of infiltration over time. The analysis extends to comparing the results of infiltration between 2023 and 2024, assesses the effects of various land use types (forest, urban, agriculture) and evaluates how soil texture and condensation affect water movement. Statistical and comparative techniques are employed to ensure data accuracy and achieve meaningful trends. Finally, the results are interpreted to understand the effective groundwater recharge plan and the spatial temporary variability of infiltration into the soil.

3.1 Study Area

The current study was conducted in 24 selected blocks within the Junagadh Taluka in the state of Gujarat to investigate the infiltration pattern into the compacted soil. The Junagadh Taluka is located in the northern part of the Saurashtra agro climatic region falling between 20°30'N to 24°00'N and longitudinal 69°00'E to 72°00'E between latitudes. Figure 2 shows the area of study.

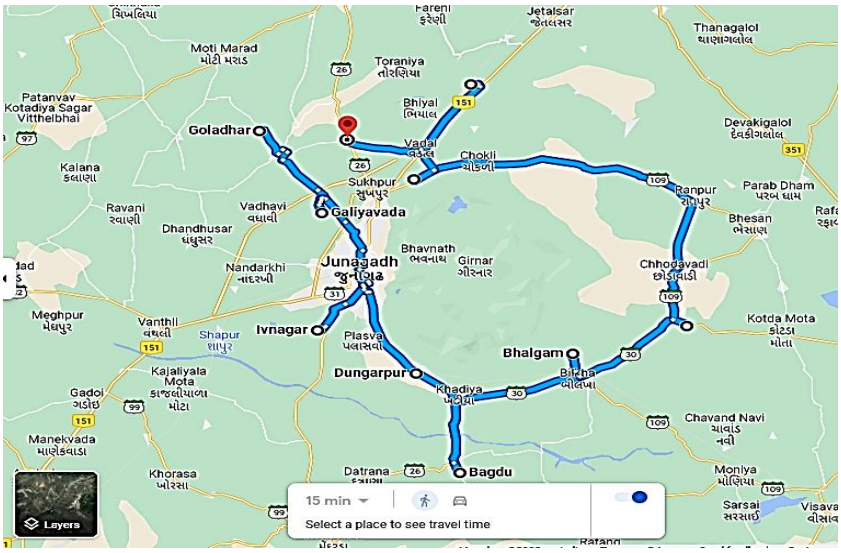

Figure 2: Study Area

The region is classified as a semi-arid area, covering a total geographical area of about 68,691 hectares (680 square kilometers). The region experiences an average annual rainfall from 800 mm to 1,200 mm (about 31 to 47 inches) which greatly affects soil moisture and infiltration characteristics. Junagadh Taluka has about 71 villages and is ruled by 51 Taluka which reflects a mixture of rural settlements and the use of agricultural land. This diverse topography and land management structure creates an ideal place to study spatial variability in soil infiltration, especially in relation to the prevalent and low paralysis soil in the entire region. The list of 24 selected villages for study is shown in Table 1.

Table 1: List of 24 Selected Villages in Junagadh Taluka

SI. No	Villages	SI. No	Villages
1	Khadiya	13	Vadhavi
2	Toraniya	14	Makhiyala
3	Ivnagar	15	Sukhpur
4	Plasva	16	Bilkha
5	Galiyavada	17	Bagdu
6	Valasimdi	18	Bhalgam
7	Majevdi	19	Nava Pipliya
8	Goladhar	20	Mandlikpur
9	Patrapsar	21	Bamangam
10	Dungurpur	22	Bhavnath
11	Padariya	23	Vadal
12	Khalilpur	24	Choki

3.2 Application of Infiltration Models: Horton and Philip Approaches

In addition to the field and laboratory-based procedures mentioned in the ASTM D3385 standard, this study involves theoretical modeling to better understand the dynamic behavior of soil infiltration. In particular, the Horton and the Philip models were considered to analyze the intrusion characteristics over time. These models provide complementary insight into infiltration processes by combining empirical comments with mathematical stability. Horton models are widely used in hydrological and geotechnical studies which over time to describe the exponential decline in the IR, accounting for both early high infiltration and stable state conditions. This

model helps to explain the measured infiltration data to the area and estimate the major parameters related to soil permeability and infiltration decay behavior.

Similarly, the Philip model integrates the effects of capillary suction and gravity on the speed of water through the soil. This is particularly applied under the position of the ponds and in homogeneous soil profiles. The model allows for assessment of two important parameters: sorptivity which represents the soil's ability to absorb water due to capillary and hydraulic conductivity representing the saturated infiltration capacity of the soil. In this study, both models work to validate and complement the field data obtained using the DRI method. Combined use of standard processes ASTM D3385 with theoretical infiltration modeling increases the functioning of research allowing deep understanding of spatial and temporary variations in soil infiltration. These models facilitate comparative analysis in various soil types and land use conditions within the study field.

3.2.1 Horton Infiltration Model

The Horton infiltration model is a widely accepted empirical approach that is used to describe the rate on which water infiltrates the soil over time. It reflects the natural behavior of soil infiltration which begins at a higher rate and gradually decreases until it becomes stable at a constant rate due to the saturation of the soil. The model is especially useful in hydrological and geotechnical engineering to simulate the surface water infiltration under the region's position.

Horton mathematically expressed the infiltration rate as Equation (1);

$$f(t) = f_c + (f_0 - f_c) \cdot e^{-kt} \quad (1)$$

Where,

- $f(t)$ represents infiltration rate at any time t (cm/h)
- f_0 denotes the Initial infiltration rate (cm/h)
- f_c signifies the final infiltration rate after saturation (cm/h)
- k indicate the decay constant (1/h), representing the rate of reduction in infiltration.
- t denote the time from the start of infiltration (in hours)

- The model assumes that the infiltration capacity decreases exponentially from an initial maximum rate f_0 to a steady minimum rate f_c, as a function of time.

- Using Microsoft Excel's Solver function for calibrating and validating infiltration Horton model, for a practical and effective approach.

3.2.2 Philip Infiltration Model

The Philip infiltration model is a physically based equation that describes the speed of water over time considering both capillary suction and gravity forces. This is especially suitable for landscapes where infiltration is in the position of ponds such as during rain or irrigation event and usually applies in hydrological and geotechnical studies. The general form of the Philip Equation (2):

$$F(t) = S \cdot t^{1/2} + K \cdot t \tag{2}$$

Here, $F(t)$ represents the cumulative infiltration at time t, S denotes the sorptivity and K denotes the hydraulic conductivity. Sorptivity reflects the soil's ability to absorb water due to capillarity while hydraulic conductivity relates to the gravity determined movement of water through the soil.

Chapter 4

Results

This section presents experimental findings of soil infiltration characteristics in different villages of Junagadh taluka for 2023 and 2024. Results contain variations in infiltration rates, soil physical properties such as dry density, bulk density and water content, and model performance evaluation using the Horton and Phillips equations. The analysis highlights spatial and temporal variability affecting soil permeability and hydrological behaviour.

Table 2: Infiltration Rates of Villages in 2023 and 2024

SI. No	Village	Infiltration Rate 2023 (cm/h)	Infiltration Rate 2024 (cm/h)	Change in Infiltration Rate (cm/h)
1	Khadiya	2.38	6.02	3.64
2	Toraniya	1.20	4.82	3.62
3	Ivnagar	2.41	2.41	0
4	Plasva	3.61	4.82	1.21
5	Galiyavada	3.61	2.41	-1.20
6	Valasimdi	2.41	4.82	2.41
7	Majevdi	1.20	2.41	1.21
8	Goladhar	2.41	3.61	1.20
9	Patrapsar	4.82	7.23	2.41
10	Dungurpur	1.20	1.20	0
11	Padariya	4.82	2.41	-2.41
12	Khalilpur	3.61	6.02	2.41
13	Vadhavi	3.61	3.61	0
14	Makhiyala	7.23	6.02	-1.21
15	Sukhpur	6.02	8.43	2.41
16	Bilkha	1.20	1.20	0
17	Bagdu	7.23	7.23	0

18	Bhalgam	8.43	9.64	1.20
19	Nava Pipliya	4.82	6.02	1.20
20	Mandlikpur	4.82	6.02	1.20
21	Bamangam	8.43	7.23	-1.20
22	Bhavnath	4.82	6.02	1.20
23	Vadal	6.02	4.82	-1.20
24	Choki	3.61	3.61	0

Table 2 shows that villages like Khadiya and Toraniya recorded the highest increases in infiltration rates from 2.38 to 6.02 cm/h and 1.20 to 4.82 cm/h respectively while Ivnagar, Dungurpur, Bilkha, Bagdu and Bhalgam showed no change. Plaswa, Valasimdi, Patraspar and Khalilpur showed moderate changes. This result indicates a notable difference in the spatial and temporal variability of soil infiltration in Junagadh taluka. Furthermore, effective soil management and reducing compaction in soils is important for improving water infiltration, groundwater recharge and sustainable agricultural production.

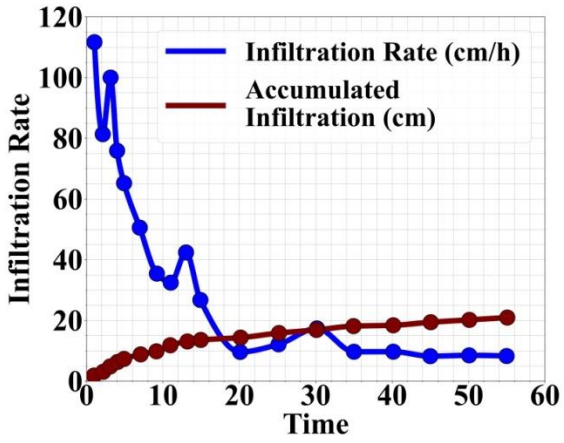

Figure 3: Infiltration Pattern at Bhalgam 2023

Figure 3 represents the infiltration dynamics at Bhalgam over the 55 min duration. Initially, the infiltration rate is very high which is about 110 cm/h reflects dry soil with high permeability. This rate decreases rapidly during the first 20 minutes due to soil saturation. After this initial stage, the infiltration rate stabilizes near 10 cm/hr indicating the original infiltration capacity of the soil. Concurrent, accumulated infiltration increases continuously reaches about 21 cm by the end suggests frequent water absorption. The pattern indicates that the soil of Bhalgam has an important initial intrusion capacity but as saturation, the rate decreases and stabilizes the retention of water and the moderate capacity of the soil for recharge capacity.

Table 3: Infiltration Rate Analysis at Bhalgam 2023

Block: 18	**Location:** Bhalgam		**Date:** 02/04/2023		**Time:** 4:55 pm	Map Coordinate 21.4600° N, 70.5919° E
Time (min)	**Intial Water Level (cm)**	**Final Water Level (cm)**	**Fall in Water Level (cm)**	**Infiltration Rate (cm/h)**	**Accumulated Infiltration (cm)**	
1	15.2	13.3	1.9	111.76	1.9	
2		11.9	1.4	82.35	3.3	
3		10.2	1.7	100.00	5	
4		9.5	1.3	76.47	6.3	
5		8.6	1.1	64.71	7.4	
7	15.4	13.7	1.7	51.52	9.1	
9		12.5	1.2	36.36	10.3	
11		11.4	1.1	33.33	11.4	Temperature 30.5^0C
13		10	1.4	42.42	12.8	
15		9.1	0.9	27.27	13.7	
20	15.1	14.2	0.8	9.64	14.5	
25		13.1	1.1	13.25	15.6	
30		11.7	1.4	16.87	17	
35		10.9	0.8	9.64	17.8	
40	14.9	14.1	0.8	9.64	18.6	Wind speed 11.5kmh
45		13.4	0.7	8.43	19.3	
50		12.7	0.7	8.43	20	
55		12	0.7	8.43	20.7	

Table 3 presents an infiltration data recorded in 2023 at Bhalgam. The infiltration rate begins at high 111.76 cm/hr during the first minute and gradually decreased as soil near saturation. The initial water level dropped from 1.9 to 1.1 cm in the initial phase, while later the gaps saw a

decline of 0.7 to 0.8 cm. The cumulative infiltration reached 20.7 cm in 55 minutes. The recorded temperature was 30.5 ° C and the wind speed was 11.5 km/h. These result highlight the moderate to high permeability of the soil, providing valuable insight to optimization of irrigation systems, drainage design and permanent land use scheme.

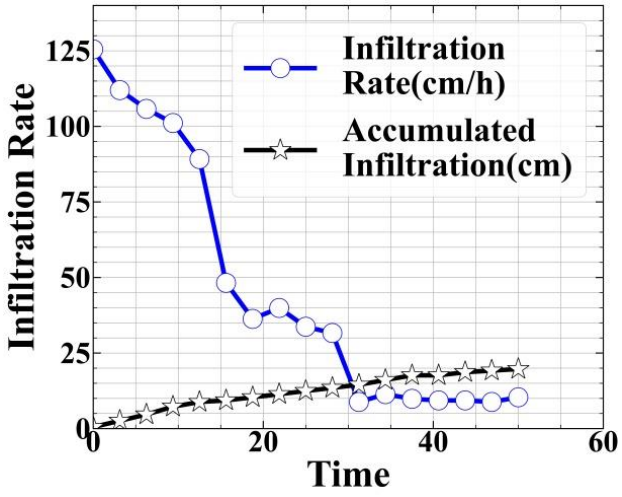

Figure 4: Infiltration pattern for Bhalgam 2024

Figure 4 illustrates the IR observed in Bhalgam during 2024. IR begins at approximately 125 cm/h decreases rapidly over time and then stabilizes at a low constant rate after approximately 35 hours. Accumulated infiltration continuously increases throughout the time showing the gradual infiltration of water into the soil. This pattern shows that initial infiltration was rapid due to high soil permeability but decreased as the soil continued to saturate. These results illustrate that infiltration for this region is temporal variable which is useful in water management and irrigation planning.

Table 4: Infiltration Rate Analysis at Bhalgam 2024

Block: 18	**Location:** Bhalgam		**Date:** 04/05/24		**Time:** 04:10 pm	**Map coordinate:** 21.4600^0 N 70.5919^0 E
Time (Min)	**Initial Water Level (cm)**	**Final Water Level (cm)**	**Fall in water (cm)**	**Infiltration Rate (cm\h)**	**Accumulated Infiltration (cm)**	
1	14.8	12.7	2.1	125.75	2.1	
2		10.9	1.9	113.77	4	

3		9.1	1.8	107.78	5.8	
4		7.4	1.7	101.80	7.5	Temperature 37^0c
5		5.9	1.5	89.82	9	
7	15	13.4	1.6	48.48	10.6	
9		12.1	1.3	39.39	11.9	
11		10.7	1.4	42.42	13.3	
13		9.5	1.2	36.36	14.5	
15		8.4	1.1	33.33	15.6	
20	15.2	14.1	0.9	10.84	16.5	
25		13.1	1	12.05	17.5	Wind Speed 16 kmh
30		12.2	0.9	10.84	18.4	
35		11.4	0.8	9.64	19.2	
40		10.6	0.8	9.64	20	
45		9.8	0.8	9.64	20.8	
50		9	0.8	9.64	21.6	

Table 4 shows IR measurements from Bhalgam recorded at a temperature of 37°C and wind speed of 16 km/h. The initial IR was higher at 125.75 cm/h which indicates a highly permeable soil. Over time, the IR gradually decreased to 9.64 cm/h 50 minutes showing the low potential of the soil because it became saturated. Demonstrating effective water absorption, accumulated infiltration reached 21.6 cm. These findings highlight the variability in the IR affected by the physical properties of soil in Junagadh Taluka outlining the significance of site specific irrigation scheme for optimal water management.

Table 5: Data Analysis of Water Content, Bulk Density, Dry Density and Infiltration Rate

Village	**Depth (cm)**	**Water Content (%)**	**Bulk Density (g/cm^3)**	**Dry Density (g/cm^3)**	**Infiltration Rate (cm/h)**
Khadiya	30-45	3.56	1.91	1.83	2.38
Toraniya	30-45	2.74	1.92	1.86	1.20
Plasva	30-45	4.42	1.89	1.81	3.61
Galiyavada	30-45	4.57	1.89	1.80	3.61
Valasimdi	30-45	3.53	1.90	1.83	2.41

Majevdi	30-45	2.66	1.92	1.86	1.20
Goladhar	30-45	3.59	1.90	1.84	2.41
Patrapsar	30-45	5.26	1.86	1.77	4.82
Padariya	30-45	5.26	1.86	1.76	4.82
Khalilpur	30-45	4.48	1.88	1.79	3.61
Vadhavi	30-45	4.52	1.88	1.79	3.61
Bilkha	30-45	2.55	1.92	1.86	1.20
Bagdu	30-45	7.33	1.82	1.69	7.23
Bhalgam	30-45	8.20	1.81	1.67	8.43
Nava Pipliya	30-45	5.42	1.86	1.76	4.82
Mandlikpur	30-45	5.22	1.86	1.76	4.82
Bamangam	30-45	8.19	1.80	1.66	8.43
Bhavnath	30-45	5.26	1.87	1.77	4.82
Choki	30-45	4.46	1.88	1.80	3.61

Table 5 displays data on water content, bulk density, dry density and infiltration rates from soil samples collected at depths (30-45 cm) across villages in Junagadh Taluka, Gujarat. This parameter indicates the impact of bulk density of the soil on water infiltration in the profiles of layered soils. The bulk density varies between 1.80 and 1.92 g/cm reflecting the soil condensation that impact directly on the speed of the water. Generally, high infiltration rates (up to 8.43 cm/h) in low bulk density soils such as Bagdu and Bhalgam villages suggest better permeability and low compaction. Conversely, high bulk density value matches with low infiltration rates as seen in Toraniya and Majevadi which reflects the compact soil layers that restrain the flow of water. The water content varies between 2.55% and 8.20% affecting the availability of soil moisture and infiltration ability. The dry density obtained from bulk density and water content supports these conclusions by portraying the physical structure of the soil. Overall, the data confirms that low bulk density increases infiltration which improves soil water retention and permeability in the layered profiles of Junagadh.

Table 6: Infiltration Model Fit Comparison (Horton vs. Philips) 2023

SI. No	Location	2023				
		Date & Time	**Temp & wind**	**Horton equation R^2**	**Philips equation R^2**	**Infiltration pattern follows**
1	Khadiya 21.5871° N, 70.2565° E	Date: 29/1/23 Time: 8:30 am	Temp: 29^0C Wind speed: 11 Kmh	R^2=0.7756	R^2 =0.6242	Horton
2	Toraniya 21.4382° N, 70.5455° E	Date: 29/1/23 Time: 2:30 am	Temp: 30^0C Wind speed: 12 Kmh	R^2=0.7539	R^2 =0.7075	Horton
3	Ivnagar 21.5025°N, 70.4182°E	Date: 11/2/23 Time: 10:15 am	Temp: 29.5˚C Wind speed: 10.5 kmh	R^2=0.9289	R^2 =0.8928	Horton
4	Palasva 21.50245°N 70.41795°E	Date: 11/2/23 Time: 4:30 pm	Temp: 31˚C Wind speed: 11.6 kmh	R^2=0.9269	R^2 =0.8626	Horton
5	Galiyavada 21.3349°N 70.2633°E	Date: 12/2/23 Time: 09:00 am	Temp: 32˚C Wind speed: 13 kmh	R^2=0.9234	R^2 =0.9286	Horton
6	Valasimdi 21.6309° N 70.4224° E	Date: 12/2/23 Time: 11:55 am	Temp: 34˚C Wind speed: 12 kmh	R^2=0.8873	R^2 =0.8640	Horton

7	Majevdi 21.6309° N 70.4224° E	Date: 17/2/23 Time: 04:10 pm	Temp: 33˚C Wind speed: 11.5 kmh	R^2=0.7372	R^2 =0.7990	Philips
8	Goladhar 21.6248° N, 70.3956° E	Date: 18/2/23 Time: 01:10 pm	Temp: 32˚C Wind speed: 12 kmh	R^2=0.9057	R^2 =0.7839	Horton
9	Patrapsar 21.5793° N, 70.3780° E	Date: 18/2/23 Time: 04:30 pm	Temp: 32˚C Wind speed: 13 kmh	R^2=0.9035	R^2 =0.8879	Horton
10	Dungurpur 21.4454° N 70.4938° E	Date: 26/2/23 Time: 11:20 am	Temp: 33˚C Wind speed: 12 kmh	R^2=0.8808	R^2 =0.6277	Horton
11	Padariya 21.4665° N 70.4737° E	Date: 26/2/23 Time: 4:10 pm	Temp: 32˚C Wind speed: 12 kmh	R^2=0.8974	R^2 =0.8886	Horton
12	Khalilpur 21.4665° N, 70.4737° E	Date: 5/3/23 Time: 1:05 pm	Temp: 33˚C Wind speed: 11 kmh	R^2=0.9362	R^2 =0.9620	Philips
13	Vadhavi 21.5639° N 70.3977° E	Date: 5/3/23 Time: 4:30 pm	Temp: 32˚C Wind speed: 11.5 kmh	R^2=0.8859	R^2 =0.9443	Philips
14	Makhiyala 21.6186° N 70.4506° E	Date: 19/3/23 Time: 1:05 pm	Temp: 30˚C Wind speed: 13.5 kmh	R^2=0.8180	R^2 =0.8285	Philips
15	Sukhpur 21.5821° N,	Date: 19/3/23 Time: 04:30 pm	Temp 30˚ C Wind speed:13	R^2=0.9395	R^2 =0.9658	Philips

	70.4663° E		kmh			
16	Bilkha 21.5821° N, 70.4663° E	Date: 1/4/23 Time: 03:30 pm	Temp: 31˚C Wind speed: 12 kmh	R^2=0.7372	R^2 =0.7990	Philips
17	Bagdu 21.3715° N, 70.5205° E	Date: 2/4/23 Time: 01:45 pm	Temp: 31˚C Wind speed: 11.5 kmh	R^2=0.9369	R^2 = 0.8712	Horton
18	Bhalgam 21.4600° N, 70.5919° E	Date: 2/4/23 Time: 04:55 pm	Temp:30˚C Wind speed: 11.5 kmh	R^2=0.9591	R^2 = 0.8970	Horton
19	Nava Pipliya 21.44575°N 70.61445°E	Date: 16/4/23 Time: 01:25 pm	Temp: 32˚C Wind speed: 10.5 kmh	R^2=0.8895	R^2 = 0.9038	Philips
20	Madlikpur 21.3493° N, 70.5317° E	Date: 16/4/23 Time: 04:50 pm	Temp: 32˚C Wind speed: 11.5 kmh	R^2=0.8902	R^2 = 0.8803	Horton
21	Bamangam 21.5890° N, 70.4919° E	Date: 7/5/23 Time: 01:10 pm	Temp: 33˚C Wind speed: 12 kmh	R^2=0.9729	R^2 =0.9327	Horton
22	Bhavnath 21.5334° N, 70.5012° E	Date: 7/5/23 Time: 05:10 pm	Temp: 32˚C Wind speed: 13.5 kmh	R^2=0.9649	R^2 = 0.9788	Philips
23	Vadal 21.6113° N, 70.4970° E	Date: 28/5/23 Time: 09:30 pm	Temp: 34˚C Wind speed: 12.5 kmh	R^2=0.9426	R^2 = 0.9021	Horton

24	Choki 21.6619° N, 70.5302° E	Date: 28/5/23 Time: 12:30 pm	Temp: 34˚C Wind speed: 12 kmh	R^2=0.9496	R^2 =0.9753	Philips

Table 6 presents infiltration data from 24 locations across different dates in 2023 analyzing temperature, wind speed, and the effectiveness of Horton and Philips infiltration equations using R^2 values. The temperature is between 29°C to 34°C with air speed from 10.5 to 13.5 km/h. The pattern of infiltration mainly followed the Horton model clarified at 15 places where its R^2 values were consecutively (eg, Bamangam: 0.9729). The Philips Model 9 locations better fit, especially in Khalilpur and Sukhpur, where it improved Horton. Overall, the two models show strong correlation, but the Horton came out more widely. In particular, the model of Horton better represented infiltration behavior in different environmental conditions, making it more reliable for general prediction in the studied field.

Table 7: Infiltration Model Fit Comparison (Horton vs. Philips) 2024

SI. No	**location**	**2024**				
		Date & Time	**Temp & wind**	**Horton equation R^2**	**Philips equation R^2**	**Infiltration pattern follows**
1	Khadiya 21.5871° N, 70.2565° E	Date: 09/03/24 Time 2:30pm	Temp: 34^0 C Wind speed: 13Kmph	R^2 = 0.8190	R^2 =0.7049	Horton
2	Toraniya, 21.4382° N, 70.5455° E	Date: 09/03/24 Time: 4:45pm	Temp: 33˚ C Wind speed: 13Kmph	R^2 = 0.8403	R^2 =0.8017	Horton
3	Ivnagar 21.5025°N,	Date: 17/3/24 Time: 09:30am	Temp: 32˚ C Wind speed:	R^2 = 0.9561	R^2 =0.8779	Horton

	70.4182°E		12 kmh			
4	Palasva, 21.50245°N 70.41795°E	Date: 17/3/24 Time: 03:30pm	Temp: 32˚ C Wind speed: 12 kmh	R^2 = 0.9425	R^2 =0.7848	Horton
5	Galiyavada 21.3349°N 70.2633°E	Date: 23/3/24 Time: 04:30 pm	Temp 35˚ C Wind speed 17 kmh	R^2 = 0.9695	R^2 =0.8952	Horton
6	Valasimdi 21.6309° N 70.4224° E	Date: 24/3/24 Time: 10:40 am	Temp: 36˚ C Wind speed: 18kmh	R^2 = 0.9470	R^2 =0.9458	Horton
7	Majevdi 21.6309° N 70.4224° E	Date: 30/3/24 Time: 04:30 pm	Temp: 37˚ C Wind speed: 12kmh	R^2 = 0.8328	R^2 =0.6960	Horton
8	Goladhar 21.6248° N, 70.3956° E	Date: 31/3/24 Time: 03:30 pm	Temp 37˚ C Wind speed: 13kmh	R^2 = 0.9602	R^2 =0.9420	Horton
9	Patrapsar 21.5793° N, 70.3780° E	Date: 31/3/24 Time: 05:05 pm	Temp: 37˚ C Wind speed: 13kmh	R^2 = 0.9577	R^2 =0.8883	Horton
10	Dungurpur 21.4454° N 70.4938° E	Date: 07/4/24 Time: 09:15 am	Temp: 33˚ C Wind speed: 12 kmh	R^2 = 0.9671	R^2 =0.8950	Horton
11	Padariya 21.4665° N 70.4737° E	Date: 07/4/24 Time: 05:10 pm	Temp: 33˚ C Wind speed: 12 kmh	R^2 = 0.9578	R^2 =0.8927	Horton
12	Khalilpur 21.4665° N,	Date: 14/4/24 Time:	Temp: 35˚ C Wind speed:	R^2 = 0.9709	R^2 =0.8873	Horton

	70.4737° E	10:00 am	14 kmh			
13	Vadhavi 21.5639° N 70.3977° E	Date: 14/4/24 Time: 05:10 pm	Temp: 34˚ C Wind speed: 14 kmh	R^2 = 0.9741	R^2 =0.9227	Horton
14	Makhiyala 21.6186° N 70.4506° E	Date: 21/4/24 Time: 09:05 am	Temp: 31˚ C Wind speed: 15 kmh	R^2 = 0.9661	R^2 =0.8886	Horton
15	Sukhpur 21.5821° N, 70.4663° E	Date: 21/4/24 Time: 04:45 pm	Temp: 35˚ C Wind speed: 15 kmh	R^2 =0.9447	R^2 =0.8395	Horton
16	Bilkha 21.5821° N, 70.4663° E	Date: 27/4/24 Time: 04:30 pm	Temp: 34˚ C Wind speed: 12 kmh	R^2 = 0.9612	R^2 =0.8865	Horton
17	Bagdu 21.3715° N, 70.5205° E	Date: 28/4/24 Time: 09:45 am	Temp: 34˚ C Wind speed: 11 kmh	R^2 =0.9693	R^2 =0.9147	Horton
18	Bhalgam 21.4600° N, 70.5919° E	Date: 4/5/24 Time: 04:10 pm	Temp: 37˚ C Wind speed: 16 kmh	R^2 = 0.9679	R^2 =0.8764	Horton
19	Nava Pipliya 21.44575°N 70.61445°E	Date: 11/5/24 Time: 03:30 pm	Temp: 38˚ C Wind speed: 14 kmh	R^2 = 0.9418	R^2 =0.8244	Horton
20	Madlikpur 21.3493° N, 70.5317° E	Date: 12/5/24 Time: 04:15 pm	Temp: 37˚ C Wind speed: 14 kmh	R^2 = 0.9586	R^2 =0.8912	Horton
21	Bamangam 21.5890° N,	Date: 17/5/24 Time: 05:30 pm	Temp: 34˚ C Wind speed:	R^2 = 0.9621	R^2 =0.8805	Horton

	70.4919° E		15 kmh			
22	Bhavnath 21.5334° N, 70.5012° E	Date: 18/5/24 Time: 09:30 am	Temp: 36˚ C Wind speed: 15 kmh	R^2 = 0.9685	R^2 =0.9021	Horton
23	Vadal 21.6113° N, 70.4970° E	Date: 19/5/24 Time: 07:30 am	Temp: 33˚ C Wind speed: 15 kmh	R^2 = 0.9616	R^2 =0.9753	Philips
24	Choki 21.6619° N, 70.5302° E	Date: 19/5/24 Time: 09:45 am	Temp: 36˚ C Wind speed: 15 kmh	R^2 = 0.9615	R^2 =0.9119	Horton

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Table 8: Suggested Water Recharge Techniques and Their Purposes for Selected Villages

SI. No	Village	Practically Suggested Water Recharging Technique	Purpose
1	Khadiya	Check Dams	Moderate to high increase in infiltration; check dam's slow runoff and promote bank infiltration.
2	Toraniya	Percolation Ponds	Previously low infiltration; ponds store runoff and gradually percolate water.
3	Ivnagar	Recharge Trenches	Consistently low; black cotton soil benefits from trench-based lateral infiltration.
4	Plasva	Farm Ponds	Medium infiltration area; farm ponds serve dual purpose: irrigation and recharge.

5	Galiyavada	Contour Bunding	Decline in rate; contour bunding prevents runoff and promotes infiltration across slope gradients.
6	Valasimdi	Recharge Wells	Increasing rate suggests better vertical movement; recharge wells bypass upper impermeable layers.
7	Majevdi	Soak Pits	Low rate near settlements; soak pits help manage domestic runoff and improve micro-infiltration.
8	Goladhar	Gabion Structures	Moderate increase; gabions reduce erosion in hilly/mixed terrain while aiding infiltration.
9	Patrapsar	Rainwater Harvesting	High rates; harvesting maximizes water use and promotes aquifer recharge via direct/roof methods.
10	Dungurpur	Injection Wells	No improvement; suggests surface layers are restrictive—direct recharge through wells is needed.
11	Padariya	Vegetative Barriers	Declining trend; vegetative barriers slow runoff, protect topsoil, and improve root-zone infiltration.
12	Khalilpur	Farm Ponds	Rising infiltration in agricultural zone; farm ponds help store and recharge locally.
13	Vadhavi	Check Dams	Stable moderate rate; check dams improve seasonal water retention and infiltration.
14	Makhiyala	Roof Rainwater Harvesting	Urban or semi-urban trend; high rates suitable for roof capture and directed recharge.
15	Sukhpur	Percolation Tanks	High values; tanks allow storage and deep percolation where groundwater recharge is viable.
16	Bilkha	Deep Bore Recharge	Persistently poor rates; deep recharge

		Wells	necessary to bypass surface sealing.
17	Bagdu	Rainwater Storage Tanks	High infiltration area; storage tanks reduce flood risk and offer controlled percolation.
18	Bhalgam	Check Dams & Recharge Wells	Excellent rates; combo approach maximizes storage and deep aquifer recharge.
19	Nava Pipliya	Farm Bunding	Medium to high; bunding minimizes runoff, retains moisture in cropping zones.
20	Mandlikpur	Recharge Shafts	Rising rates suggest suitability for shaft-based vertical recharge in sandy or fractured zones.
21	Bamangam	Rainwater Harvesting	High infiltration; rooftop and open area runoff can be efficiently harvested.
22	Bhavnath	Percolation Tanks	Moderate-high infiltration supports tank percolation into deeper soils.
23	Vadal	Contour Trenches	Slight drop in infiltration suggests need to retain water through slope-based trenching.
24	Choki	Recharge Trenches	Constant moderate values; trenches enhance infiltration and reduce overland flow.

Chapter 5
Conclusion

This research provides valuable insights into the spatial and temporal variability of soil infiltration within Junagadh Taluka. Field measurements exposed significant differences in IRs among villages mainly influenced by soil texture, bulk density and water content. The results confirm that soils with lower compaction allow higher infiltration, enhancing ground water recharge potential. Model performance assessment revealed that the Horton equation more precisely symbolizes infiltration behavior in most locations compared to the Philips model. These results support improved land and water management strategies for sustainable agriculture. The study emphasizes the significance of site specific soil evaluation for effective hydrological planning and resource conservation.

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Experimental Study on Infiltration Pattern in the Soil of Junagadh (Gujarat-India)

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Abstract: Infiltration plays a pivotal role in both irrigated and rainfed agriculture, serving as a fundamental component of efficient environmental planning systems. These studies sought to model infiltration rate (IR) and assess its spatial variability within Junagadh Taluka, Gujarat, India. Employing a double-ring infiltrometer, field measurements were conducted across 24 blocks, encompassing a diverse range of soil types. The study observations revealed varying infiltration rates among villages, with rates exceeding 4.82 cm/h indicating permeable soils, while rates below 1.2 cm/h suggested compacted soils. Initial infiltration rates were uniformly high across all blocks but demonstrated a gradual decrease with successive readings. Furthermore, forested areas exhibited higher infiltration rates compared to urban and grassland regions. These findings underscore the importance of understanding infiltration dynamics for effective water management and environmental planning. A detailed information Table was developed, depicting infiltration rates across the 24 blocks, thereby providing valuable insights for decision-makers involved in hydrological processes, land-use planning, and water resource management. This study enhances the comprehension of soil-water interactions and offers practical implications for the region's sustainable agricultural practices and environmental conservation efforts.

Keywords: Double-ring infiltrometer; infiltration rate; Junagadh taluka; Gujarat; spatial variability.

1. Introduction

The soil-water infiltration process holds pivotal importance across various fields including pedology, hydrology, drainage, hydrogeology, and irrigation systems. The capability of water to permeate soil strata is known as infiltration. A soil stratum's total capacity to absorb water from irrigation or rainfall in a given time is known as the cumulative infiltration; the velocity at which water enters the soil in a given period is known as the instantaneous infiltration rate; and the total capacity to absorb water from irrigation or rainfall in a given time is known as the infiltration rate [Anni, Cohen, et a., (2020); Wu, Cui, et al., (2021); Pahlavan-Rad, Dahmardeh, et al., (2020)]. The rate at which water seeps into the soil

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Spatial Variation of Infiltration Rates in Relation to Soil Physical Properties tn Junagadh Taluka (Gujarat-India)

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Abstract: *Infiltration is a critical hydrological process influencing soil moisture, groundwater recharge, and agricultural productivity. Understanding the variability in infiltration rates across regions with semi-compacted soils is essential for sustainable water resource management. However, existing studies often fail to consider the combined effects of environmental factors, such as wind speed and temperature, along with soil structure and land use patterns. These limitations hinder the ability to comprehensively analyse infiltration dynamics, particularly in regions like Junagadh Taluka, Gujarat, India. This study addresses these gaps by evaluating infiltration rates across 24 blocks of Junagadh Taluka using a double-ring infiltrometer. The proposed work investigates the spatial and temporal variability in infiltration rates from 2023 to 2024, considering influencing factors such as soil compaction, vegetation cover, hydraulic conductivity, and environmental conditions. High-resolution measurements were conducted, accounting for soil properties, rainfall history, and surface characteristics, while incorporating map coordinates to analyse spatial distribution patterns. The results reveal a general increase in infiltration rates across most villages, with significant improvements observed in Khadiya (3.64 cm/h) and Toraniya (3.62 cm/h), attributed to better water management practices. Conversely, some villages, like Padariya (-2.41 cm/h) and Makhiyala (-1.21 cm/h), showed declines due to soil compaction and environmental degradation. The study highlights the importance of localized factors in influencing infiltration rates and provides valuable insights into improving water management practices for semi-compacted soils. The infiltration rates, water content and densities are assessed in five villages and the statistical results show the spatial variation and temporal trends as affected by the types of soils and the environment. This research contributes to understanding infiltration dynamics, offering practical recommendations for sustainable soil and water management in similar agro-ecological regions.*

Keywords: *Soil Infiltration Rate, Double Ring Infiltrometer, Soil Physical Properties, Land-Use Patterns, Sustainable Water Management*

INTRODUCTION

Soil water infiltration process is vital in many disciplines which include physical geography, soil science, hydrology, drainage, hydrogeology and irrigation engineering. This then call infiltration, which is the ability of water percolating through soil layers (Chunilal et al., 2024). The amount of water in a soil stratum from irrigation or rainfall during a certain period of time is called the cumulative infiltration; the rate at which water enters the soil during a certain period of time is called the instantaneous infiltration rate; and the total capacity of the soil to take water from irrigation or rainfall during a certain period of time is called the

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"Influence of Bulk Density on Water Infiltration Rates in Layered Soil Profiles: Model-Based Analysis for Junagadh Taluka, Gujarat"

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Abstract: -

This study investigates the relationship between soil bulk density, dry density, and water infiltration rates across layered soil profiles in Junagadh taluka, Gujarat, India. Employing core cutter sampling and double-ring infiltrometer tests, soil properties—including bulk density, dry density, and moisture content—were analyzed at depths of 30–45 cm. The findings reveal a significant inverse correlation between bulk density and infiltration rate, with compacted soils demonstrating markedly lower permeability. In the villages like Patrapsar and Padariya, which are characterized by lower bulk density, showed higher infiltration rates, whereas soils in the villages Toraniya and Majevdi are heavily compacted consequently restricted water movement. In the Statistical analysis a strong negative correlation (r = -0.88) is indicated, with bulk density explaining 77% of the variability in infiltration rates. These findings show that there is a crucial role of soil compaction management in layered profiles to increase irrigation efficiency and reduce environmental degradation in agricultural areas. The integration of field measurements, Horton's modeling approach, and geospatial analysis provided a comprehensive understanding of infiltration dynamics and performance of Horton model 62.5% in 2023 year to 95.8% in 2024 year compare with Philip's model.

Key words:- Soil, bulk density, dry density, water content, infiltration rate, infiltration model

1. Introduction

Overview of Soil Physical Properties

Bulk density, moisture content and infiltration rate are some of the characteristics that show if the soil is healthy. Bulk density shows how much soil there is in a certain amount of space and can indicate how tightly and freely the soil particles fit together. It not only controls how much and how fast water stays and flows in soil, but it also affects how soil is structured, stays ventilated and is permeable (Choudhary & Sarin, 2021). Water content is the ratio of water to the soil that is not water and describes how much water is actually offered to the roots of plants and organisms inside the soil. Soil texture, its structure and compaction decide the rate at which water can seep into the soil (Srinivasan et al., 2020). Assessing these soil properties shows whether it supports high quality agriculture, manages water properly and limits negative effects on nature. Having a clear idea of the links among bulk density, water content and infiltration rate is important for choosing sustainable ways to use land and water, mainly in places that could have issues with erosion or excess water (Kumar & Singh, 2019).

Problem Statement

Soil bulk density affects how much water is able to penetrate through soil. A high bulk density of soil makes pore spaces smaller and blocks water which leads to reduced infiltration and an increased risk of waterlogging or surface runoff (Bhardwaj & Kapoor, 2021). Soils with low bulk density have more air and water spaces inside them which makes them able to take water in more quickly and absorb it faster. However, the ground of this kind needs to be handled cautiously, for it may cause serious issues with drainage. The layered soil can have different textures or even types which evidently increases the number of problems. As the layers in

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A Review on Infiltration Patterns in Different Types of Soils

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Abstract: ***A hydrological phenomenon that occurs in nature is infiltration. It is a difficult, nonlinear procedure. The process by which water at the soil's surface penetrates the structure is known as infiltration. The depth of the water layer that may saturate the soil in one hour is typically used as a measurement (in mm or cm). Various models, and methods are used for evaluating the infiltration rate. Significant scientific effort has been put in over the past few decades to improve infiltration process by many researchers across world. Thus, present review gives magnificent information regarding infiltration rates on different types of soil around the world and research work done in India is also discussed as infiltration rate is crucial for drainage and irrigation effectiveness since it maximizes water availability while reducing erosion. Hence, paper focuses on reviewing different infiltration patterns, challenges and future work to overcome these challenges as soil infiltration rate continues to be a subject of interest so many researchers have done a number of research papers on this topic, thus reviewing the study of it.***
Keywords: Infiltration Rate, Soil, Water, Infiltrometer, Infiltration Model, Survey Methodology.

I. INTRODUCTION

The highest IR (Infiltration Rate) were seen in forest ground covers (leaf litter) and forest land covers [1]. External variables initial soil water content, rainfall process, land use type and soil characteristics soil texture, structure, bulk density are the two primary categories that influence infiltration . In soil technology, the term "infiltration rate" refers to a measurement of how quickly soil can absorb rainwater [2]. Infiltration rates are maximum close to stems and quickly decrease as distance increases. A pattern of radially declining infiltration refers to the fact that the infiltration rates of the soil surface inside groves display a broad range of variation and are often identical to those of intergrove soils. To evaluate the field infiltration rate on sandy loam and different kinds of soils, researchers are evaluating the infiltration models. By comparing the soils' actual and expected infiltration rates, the Kostiakov, modified Kostiakov, and Horton infiltration models were determined [3, 4]. For Aba region soils, Philip's model was able to predict the depths of water infiltration [5]. Infiltration is frequently higher beneath plant canopies than beneath interspaces in both grassland and shrubland. Canopies are oases with increased soil moisture [5]. The volcanic soil with ponderosa pine vegetation had the biggest variation in IR with a ratio of steady-state IR in burnt locations to unburned soils [6]. A thorough understanding of the soil's spatial water infiltration characteristics, which vary from site to site and are more complicated due to non-uniformity, might improve agricultural water usage effectiveness and reduce water-related problems [7]. Further, Compacted soils due to the motion of agricultural technology have low IR which to runoff generation. Preparation and creation of water resource systems as well as for comprehending the rainfall-runoff process, and IR data for innumerable soil types are crucial. For the motive of calculating infiltration rate, a model primarily based totally on complementary error characteristic peak ERFC is used [8].

In order to compare the empirical equation depending on different models which are used for evaluating IR [9] and to find the best soil IR model based on specific physical soil features and to validate the model, multiple linear regression analysis (MLR) was used to compare the estimated rate with the field-measured rate of infiltration [10]. The impact of different soil conditions on infiltration rate helps developing a better knowledge of the variations and local soil infiltration rate [7, 11] Hence, present review paper focuses on reviewing different state-of-art approaches for soil infiltration in India and around the work. Thus, the primary objective of the review paper includes,

- To review different pattern used to estimate soil infiltration in India and world.
- To perform comparative analysis for identifying different infiltration patterns used across India
- To encounter challenges faced by the existing works and deliberate on future recommendation of the model.

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